CERAMIC POWDER IN CONCRETE BY PARTIAL REPLACEMENT OF CEMENT- A LITERATURE ANALYSIS

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ABSTRACT
Ceramic products made up with different raw materials like china clay, ball clay, potash feldspar, dolomite, talc and different chemicals for a glazing and finishing. Ceramic production conducts on temperature 200°C to 2000°C, So the possibility of pozzolonic reactivity in such products, Which is responsible for long term strength and good durability. Here some literature paper analysis done, which are base on ceramic material partially replaced by cement in concrete. In such paper authors conducted mechanical properties tests and durability tests. They tried to replace ceramic material with cement up to 50 % with M-20 to M-40 grade of concrete.

1. INTRODUCTION
Pozzolanic concretes are used extensively throughout the world where oil, gas, nuclear and power industries are among the major users. The applications of such concretes are increasing day by day due to their superior structural performance, environmental friendliness, and energy conserving implications. The search for alternative binders, or cement replacement materials, has been carried out for decades. Research has been conducted on the use of fly ash, volcanic ash, volcanic pumice, pulverized-fuel ash, blast slag and silica fume etc. as cement replacement material. Fly ash and others are pozzolanic materials because of their reaction with lime liberated during the hydration of cement. These materials can also improve the durability of concrete and the rate of gain in strength and can also reduce the rate of liberation of heat, which is beneficial for mass concrete. Concretes containing mineral admixtures are used extensively throughout the world for their good performance and for ecological and economic reason.

Utilization of that material in concrete may responsible for increase strength and durability as well reducing the environmental problem of their disposing. Hence it may conserve natural resources and reducing usage of cement, so the cost of cement deceases due to such pozzolonic materials.
The overall size of the Indian ceramic industry is approximately Rs 18,000 crores. The production during 2011-12 stood at approx. 600 million square meters. In the ceramic industry, about 8% to 10% waste material is generated from the total production. Wastages generated in different manner should be 8 to 10% per production so INDIA generated app. 55 million square meters/year. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation. Different types of ceramic products are:

- Wall And Floor Tiles
- Bricks And Roof Tiles
- Table-And Ornamental ware (Household Ceramics)
- Refractory Products
- Sanitary ware
- Technical Ceramics
- Vitrified Clay Pipes
- Expanded Clay Aggregates

The Ceramic industries are dumping the waste in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal.

The advancement of concrete technology can reduce the consumption of natural resources. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, arguable superior products, and severe hazards in the environment.

Ceramic powder is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Ceramic waste powder is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health.
2. Literature analysis

2.1 Re-Use Of Ceramic Industry Wastes for the Elaboration of Eco-Efficient Concrete

Amitkumar D. Raval, Dr. Indrajit N. Patel, Prof. Jayeshkumar Pitroda

Student of final year M.E. C E & M, Assistant Professor & Research Scholar, B.V.M. Engineering College, V.V.Nagar, Applied Mechanics Department, BBIT, V.V.Nagar-Gujarat-India

Inferences

- Here the aim of the Amitkumar D. Raval is to study the physical and mechanical properties of different laboratory-mixed concretes, using various proportions of supplementary materials generated from industrial waste.
- He studied the (OPC) cement has been replaced by ceramic waste in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-30 grade concrete.
- Test results have reflected, the compressive strength achieved up to 30% replacement of cement with ceramic waste will be optimum without effecting properties of fresh and hardened concrete.
- He used metallic cube moulds (150*150*150 mm) were casted for compressive and split strength.

Material

- The Cementitious material used by Amitkumar D. Raval was OPC and CERAMIC. The ordinary Portland cement 53 grade conforming to IS: 8112-1989 was used in this investigation.
- The principle waste coming into the ceramic industry is the ceramic powder, specifically in the powder forms. Ceramic wastes are generated as a waste during the process of dressing and polishing.

Design Mix

- A mix M30 grade was designed as per Indian Standard method (IS10262-2009) and the same was used to prepare the test samples.
Table 1-Design mix proportion for (M30 mix)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Concrete Type</th>
<th>Concrete Design Mix Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W.C. ratio</td>
<td>C (Kg/m³)</td>
</tr>
<tr>
<td>1</td>
<td>0.43</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>0.43</td>
<td>0.90</td>
</tr>
<tr>
<td>3</td>
<td>0.43</td>
<td>0.80</td>
</tr>
<tr>
<td>4</td>
<td>0.43</td>
<td>0.70</td>
</tr>
<tr>
<td>5</td>
<td>0.43</td>
<td>0.60</td>
</tr>
<tr>
<td>6</td>
<td>0.43</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Test performed on compression testing machine after 7, 14 and 28 days normal curing respectively for different concrete type and concluded the result.

Table 2-Compressive Strength of cubes (150X150X150)

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Average Compressive Strength [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 days</td>
</tr>
<tr>
<td>C0</td>
<td>27.14</td>
</tr>
<tr>
<td>C1</td>
<td>25.52</td>
</tr>
<tr>
<td>C2</td>
<td>23.77</td>
</tr>
<tr>
<td>C3</td>
<td>22.63</td>
</tr>
<tr>
<td>C4</td>
<td>20.45</td>
</tr>
<tr>
<td>C5</td>
<td>18.98</td>
</tr>
</tbody>
</table>

Conclusion

- The Compressive strength of M30 grade concrete little decreases when the replacement of cement with ceramic powder up to 40% by weight of cement and further replacement of cement with ceramic powder greater decreases the compressive strength.
- Concrete on 40% replacement of cement with ceramic powder, compressive strength obtained is 31.83 N/mm² and vice-versa the cost of the cement is reduced up to 18.62% in M30 grade and hence it becomes more economical without compromising concrete strength than the standard concrete.
- Utilization of ceramic waste and its application for the sustainable development of the construction industry is the most efficient solution and also address the high value application of such waste.
2.2 Eco-Efficient Concretes: Use of Ceramic Powder As A Partial Replacement Of Cement

Amitkumar D. Raval, Indrajit N. Patel, Jayeshkumar Pitroda

Inferences

- The ceramic industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes.
- In the ceramic industry, about 15%-30% production goes as waste. These wastes pose a problem in present-day society, requiring a suitable form of management in order to achieve sustainable development.
- In this paper the (OPC) cement has been replaced by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-25 grade concrete.
- Three cube samples were cast on the mould of size 150*150*150 mm for each 1:1.80:3.38 concrete mix with partial replacement of cement with a w/c ratio as 0.48 were also cast.

Materials

- The Cementitious material used by Amitkumar D. Raval was OPC and Ceramic material. The ordinary Portland cement 53 grade conforming to IS:8112-1989 was used in this investigation.
- Ceramic material is hard, rigid. It is estimated that 15 to 30% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill.
- The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is being use. The Flakiness and Elongation Index were maintained well below 15%.
- Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand is used in combination as fine aggregate conforming to the requirements of IS:383.

Design mix material

- A mix M25 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples.
Experimental Method

➢ Compressive strength tests were performed on compression testing machine using cube samples. Three samples per batch were tested with the average strength values reported in this paper.

Table 4-Compressive strength of cubes (150x150x150) for M25 mix at 7, 14, 28 days

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Average Compressive Strength [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 days</td>
</tr>
<tr>
<td>B0</td>
<td>25.39</td>
</tr>
<tr>
<td>B1</td>
<td>23.67</td>
</tr>
<tr>
<td>B2</td>
<td>21.65</td>
</tr>
<tr>
<td>B3</td>
<td>20.04</td>
</tr>
<tr>
<td>B4</td>
<td>18.11</td>
</tr>
<tr>
<td>B5</td>
<td>16.06</td>
</tr>
</tbody>
</table>

Conclusions

➢ The Compressive Strength of M25 grade concrete little decreases when the replacement of cement with ceramic waste up to 30% by weight of cement and further replacement of cement with ceramic powder greater decreases the compressive strength.

➢ Concrete on 30% replacement of cement with ceramic waste, compressive strength obtained is 26.77 N/mm² and vice-versa the cost of the concrete is reduced up to 13.27% in M25 grade and hence it becomes more economical without compromising concrete strength than the standard concrete. It becomes technically and economically feasible and viable.

➢ Utilization of ceramic waste and its application are used for the development of the construction industry, Material sciences.

➢ It is the possible alternative solution of safe disposal of ceramic waste.
2.3 Ceramic Waste: Effective Replacement Of Cement For Establishing Sustainable Concrete

Amitkumar D. Raval, Dr. Indrajit N. Patel, Prof. Jayeshkumar Pitroda
Student of final year B.V.M. Engineering college, V.V.Nagar,
Applied Mechanics Department, BBIT, V.V.Nagar-Gujarat-India.
Assistant Professor B.V.M. Engineering College, V.V.Nagar-Gujarat-India.

Inferences
➢ Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15%-30% waste material generated from the total production. This waste is not recycled in any form at present. This leads to serious environmental problems and pollution.
➢ It is most essential to develop eco-friendly concrete from ceramic waste. Amitkumar D. Raval study the (OPC) cement has been replaced by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight of M-20 grade concrete.

Experimental materials
1. Ceramic waste
➢ Ceramic wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 to 30% waste are produced of total raw material used.
➢ Ceramic waste can be used in concrete to improve its strength and other durability factors. Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand as a supplementary addition to achieve different properties of concrete.

Table 5-Chemical properties of ceramic waste

<table>
<thead>
<tr>
<th>Materials</th>
<th>Ceramic Powder (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>63.29</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>18.29</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>4.32</td>
</tr>
<tr>
<td>CaO</td>
<td>4.46</td>
</tr>
<tr>
<td>MgO</td>
<td>0.72</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.16</td>
</tr>
<tr>
<td>K₂O</td>
<td>2.18</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.75</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.10</td>
</tr>
<tr>
<td>CL</td>
<td>0.005</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.61</td>
</tr>
<tr>
<td>SrO</td>
<td>0.02</td>
</tr>
<tr>
<td>Mn₂O₃</td>
<td>0.05</td>
</tr>
<tr>
<td>L.O.T</td>
<td>1.61</td>
</tr>
</tbody>
</table>

Source: GEO TEST HOUSE, Baroda, Gujarat

Design Mix

www.jiarm.com
A mix M20 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples. The design mix proportion is done in Table.

**Table 6-Design mix proportion for (M20 mix)**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Concrete Type</th>
<th>W/C ratio</th>
<th>C</th>
<th>F.A.</th>
<th>C.A.</th>
<th>C.W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A0</td>
<td>0.55</td>
<td>1.60</td>
<td>1.00</td>
<td>3.84</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>A1</td>
<td>0.55</td>
<td>0.60</td>
<td>1.00</td>
<td>3.84</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>A2</td>
<td>0.55</td>
<td>0.80</td>
<td>1.00</td>
<td>3.84</td>
<td>0.20</td>
</tr>
<tr>
<td>4</td>
<td>A3</td>
<td>0.55</td>
<td>1.00</td>
<td>1.00</td>
<td>3.84</td>
<td>0.30</td>
</tr>
<tr>
<td>5</td>
<td>A4</td>
<td>0.52</td>
<td>0.50</td>
<td>1.50</td>
<td>3.84</td>
<td>0.50</td>
</tr>
</tbody>
</table>

W= Water, C= cement, F.A. = Fine Aggregate, C.A. = Coarse Aggregate

**Experimental methodology**

- Concrete contains cement, water, fine aggregate, coarse aggregate and grit. With the control concrete, i.e. 10%, 20%, 30%, 40%, and 50% of the cement is replaced with ceramic waste.
- Three cube samples were cast on the mould of size 150*150*150 mm for each 1:1.80:3.84 concrete mix with partial replacement of cement with a w/c ratio as 0.52 were also cast.
- The loading rate on the cube is 35 N/mm² per min. The comparative studies were made on their characteristics for concrete mix ratio of 1:1.80:3.84 with partial replacement of cement with Ceramic waste as 10%, 20%, 30%, 40% and 50%.

**Table 7-Compressive strength of cubes (150x150x150) for m25 mix at 7, 14, 28 days**

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Average Compressive Strength [Nm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 days</td>
</tr>
<tr>
<td>A0</td>
<td>22.55</td>
</tr>
<tr>
<td>A1</td>
<td>21.98</td>
</tr>
<tr>
<td>A2</td>
<td>20.38</td>
</tr>
<tr>
<td>A3</td>
<td>18.60</td>
</tr>
<tr>
<td>A4</td>
<td>16.48</td>
</tr>
<tr>
<td>A5</td>
<td>14.95</td>
</tr>
</tbody>
</table>
Table 81-Total cost of materials for m20 design mix concrete (1:1.80:3.84) per m³

<table>
<thead>
<tr>
<th>C.T.</th>
<th>C.</th>
<th>F.A.</th>
<th>C.A.</th>
<th>C.W.</th>
<th>Admixture</th>
<th>Total Cost/m³</th>
<th>% Cost Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>325.50</td>
<td>730.20</td>
<td>1265.30</td>
<td>0.00</td>
<td>2.00</td>
<td>5325.53</td>
<td>-</td>
</tr>
<tr>
<td>A1</td>
<td>292.95</td>
<td>730.20</td>
<td>1265.30</td>
<td>32.55</td>
<td>2.00</td>
<td>5100.51</td>
<td>4.22</td>
</tr>
<tr>
<td>A2</td>
<td>260.40</td>
<td>730.20</td>
<td>1265.30</td>
<td>65.10</td>
<td>2.00</td>
<td>4875.49</td>
<td>8.45</td>
</tr>
<tr>
<td>A3</td>
<td>227.85</td>
<td>730.20</td>
<td>1265.30</td>
<td>97.65</td>
<td>2.00</td>
<td>4650.48</td>
<td>12.67</td>
</tr>
<tr>
<td>A4</td>
<td>195.30</td>
<td>730.20</td>
<td>1265.30</td>
<td>130.20</td>
<td>2.00</td>
<td>4425.91</td>
<td>16.89</td>
</tr>
<tr>
<td>A5</td>
<td>162.75</td>
<td>730.20</td>
<td>1265.30</td>
<td>162.75</td>
<td>2.00</td>
<td>4200.44</td>
<td>21.12</td>
</tr>
</tbody>
</table>

Conclusion

- The Compressive Strength of M20 grade Concrete little decreases when the replacement of Cement with Ceramic Powder up to 30% replaces by weight of Cement and further replacement of Cement with Ceramic Powder greater decreases the Compressive Strength.
- Concrete on 30% replacement of Cement with Ceramic Powder, Compressive Strength obtained is 22.98 N/mm² and vice-versa the cost of the cement is reduced up to 12.67% in M20 grade.
- It is the possible alternative solution of safe disposal of Ceramic waste.

2.4 Compressive strength and durability properties of ceramic wastes based concrete

Fernando Pacheco-Torgal, Said Jalali

Inference

- Fernando Pacheco and Jalali presents an experimental study on the properties and on the durability of concrete containing ceramic wastes by several concrete mixes by replacing 20% cement by ceramic waste. And mechanical and durability performance is checked on experiments.
- The cost of cement represents more than 45% of the concrete cost, so its helps to reduce the cost of concrete.
- By replacing cement with ceramic waste will give many environmental benefits.
- Results got by Fernando Pacheco also shows that concrete mixtures with ceramic waste perform better than the control concrete mixtures concerning compressive strength, capillarity water absorption etc.
Experimental work

Material

Ceramic wastes can be separated in two categories:

- First is all single fired wastes generated by the structural ceramic factories such as brick, blocks and roof tiles.
- Second is all double fired waste produced in stoneware ceramic such as wall, floor tiles and sanitary ware.

Design mix

- Mixes with 20% replacement of cement by ceramic powder were also prepared.
- Replacing natural sand by ceramic sand.
- Coarse granite aggregate where replaced by ceramic coarse aggregate.

Experiment

- Fernando Pacheco conducts many experiments which are follows.
  - Compressive strength
  - Vacuum water absorption
  - Capillary water absorption
  - Oxygen permeability
  - Water permeability
  - Chloride diffusion test

Results and discussion

Compressive strength:

- By 20% replacement of cement with ceramic powder gives highest strength.
- The results obtained indicate, as expected, large differences in early curing ages and smaller differences at long curing ages.
- The concrete has the worst mechanical performance at early ages, but for 90 days curing the compressive strength activity index of the mixture reaches 90.4%.
- Higher curing temperatures are used in concrete pre-fabrication for accelerated moulding. Because of Higher curing temperatures increase the rate of pozzolanic activity.

Durability performance:

- With the exception of the CB (Ceramic Bricks) mixture which has a 5% higher vacuum water absorption than the control mixture.
The oxygen permeability it can seem that two mixes (ceramic bricks and sanitary ware) shows values slightly higher than the control mixes.

Chloride without exception has higher durability performance which confirms the positive impact of the ceramic additions.

Figure 1-Water penetration & Chloride diffusion test

Relation between Compressive strength and Water permeability with respect to curing period of different mixes shown in below graph.

Where,
CB- Ceramic Bricks mix
WSTF-White stoneware twice-fired mix
SW- Sanitary ware mix
WSOF-White stoneware once-fired mix

Figure 2-Compressive strength of concretes with ceramic Powder at different Curing days

Figure 3-Water and oxygen permeability of concretes with ceramic powder

Conclusions:

Fernando Pacheco concluded that concrete with ceramic waste powder has minor strength loss that is dependent on the pozzolanic reactivity of the different ceramic wastes. But it possess durability performance has increased.
2.5 Application of Waste Ceramics as Active Pozzolana in Concrete Production

Eva Vejmelková 1+, Tereza Kulovaná 1, Martin Keppert 1, Petr Konvalinka 1, Michal Ondráček 2, Martin Sedlmajer 2 and Robert Černý 1

1 Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, CTU in Prague, Czech Republic

2 Institute of Technology of Building Materials and Components, Faculty of Civil Engineering, BUT Brno, Czech Republic

Inference

➢ According to Eva and Tereza Waste ceramic materials may become a cheaper but almost equivalent alternative to metakaolin or ground granulated blast furnace slag, fly ash and other materials as supplementary binder in concrete.

➢ Clay minerals become highly reactive when they are incinerated at temperatures between 600-900°C and then ground to cement fineness. They are mainly formed by siliceous and aluminous compounds.

➢ If they are then mixed with calcium hydroxide and water, they undergo pozzolanic reaction and form compounds with enhanced strength and durability. Therefore, they have a potential to be used in mortar and concrete.

Materials

➢ The composition of the studied concrete mixes is shown in Table. They were prepared with Portland cement CEM I 42.5 R as the main binder. The specific surface area of cement was 341 m2/kg. A part of cement (10 - 60% by mass) was replaced by fine-ground ceramics, the specific surface area was 336 m2/kg.

Table 9. Mix proportion with variation of ceramic materials

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount in kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM 1425 R, Morci</td>
<td>360</td>
</tr>
<tr>
<td>Fine-ground ceramics</td>
<td>36</td>
</tr>
<tr>
<td>Aggregates 9-4 mm</td>
<td>910</td>
</tr>
<tr>
<td>Aggregates 4-8 mm</td>
<td>225</td>
</tr>
<tr>
<td>Aggregates 3-15 mm</td>
<td>555</td>
</tr>
<tr>
<td>Plasticizer Mapei Dynamon SX</td>
<td>3.96</td>
</tr>
<tr>
<td>Water</td>
<td>146</td>
</tr>
</tbody>
</table>

➢ The measurement of material parameters was done after 28 days. The following specimens’ sizes were used in the experiments: basic physical properties - 50 x 50 x 50 mm, compressive strength – 150 x 150 x 150 mm, bending strength - 100 x 100 x
400 mm, water vapor transport properties and water transport properties - 100 x 100 x 20 mm, thermal properties - 70 x 70 x 70 mm.

Experiments

Here author conducted different mechanical and durability properties tests which are mention below:

- Basic physical properties
- Pore structure
- Mechanical properties
- Water vapor transport properties
- Water transport properties
- Thermal properties

Results and discussion

Basic Physical Properties

Materials with higher amount of ground ceramics achieved about 2% lower bulk density than reference material BC2-ref. The values of matrix density were within about 3% for all materials. The highest matrix density achieved BC2-60 with 60% of fine-ground ceramics, the lowest BC2-ref without pozzolana admixtures. The highest porosity had material BC2-60 with the highest amount of supplementary cementing materials, the lowest porosity achieved the reference material BC2-ref.

Table 10. Physical and Mechanical properties with pore structure
Pore Structure
The pore size distribution of all materials is presented in Figure in form of cumulative curve. The total pore volume was increasing with increasing fine-ground ceramics content; the mean pore radius increased slightly as well.

Mechanical Properties
The mechanical properties of five studied concretes are shown in Table 3. The replacement of Portland cement by find-ground ceramics of up to 20% led to only about 10% decrease in compressive strength and 3% decrease in bending strength, which was still acceptable. For the replacement level higher than 20% of mass of cement the compressive strength was affected in much higher extent than bending strength. For BC2-60 the compressive strength was more than two times lower as compared with the reference concrete mixture BC2-ref but the bending strength was only about 20% lower.

Water Vapor Transport Properties
The results of measurements of water vapor transport properties of the analyzed materials are presented in Table. Comparing the data measured for all studied materials in both cases (dry cup, wet cup), we can see that the lowest $\mu$ value achieved material BC2-60 with 60% of fine-ground ceramics which was in a good qualitative agreement with the porosity data in Table 4. The highest water vapor diffusion resistance factor in both cases had BC2-ref without pozzolana admixtures which exhibited the lowest porosity.

Water Transport Properties
The results of water sorptivity measurements are presented in Table. They were in a good qualitative agreement with the open porosity data (Table ). The liquid water transport parameters increased with the increasing amount of fine-ground ceramics in the mix. The lowest water absorption coefficient had the reference material BC2-ref, about two times lower than BC2-60 with the highest amount of fine-ground ceramics. The comparison of apparent moisture diffusivities was similar to water absorption coefficients, as the differences in porosity were lower than those in water absorption coefficient.
Table 11. Water vapor transport, water transport and thermal properties

Thermal Properties
Thermal properties of studied concretes are shown in Table. We can see that the values of thermal conductivity of studied concretes in dry state were in a qualitative agreement with open porosity results. The thermal conductivity decreased with the increasing amount of Portland-cement replacement by fine-ground ceramics.

Conclusion
The experimental results presented in this paper showed that waste ceramic ground to an appropriate fineness can be considered a prospective pozzolana material suitable for the replacement of a part of Portland cement in concrete industry. This solution may have significant environmental and economical consequences. Waste ceramic as recycled material used in concrete production presents no further CO2 burden to the environment, and its price is much lower as compared to Portland cement.

CONCLUSIONS
- Ceramic powder as cementitious material will be good for economy and environment. It can be reducing cost of cement 20% to 30% for M30 and above grade with 20% replacement.
- Ceramic powder has very good pozzolonic reactivity due to their manufacturing process on temperature 200°C to 2000°C.
- Optimum percentage of ceramic powder for replacement is 20%-30% as cementations material.
- Compressive strength of concrete increases up to 30-40% of replacement based on pozzolonic activity.
- More than 30-40% replacement by weight of cement strength decreases.
Some time with increasing percentage of material decrease in strength posses increase duration.

All different ceramic materials have different pozzolonic reactivity.

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